<u>Magma Modification in the central Sierra Nevada batholith</u>

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<u>Introductory statement for instructors:</u>

This laboratory exercise has been used in my upper-level petrology course for a few years. It comes toward the end of our journey through igneous rocks. We have talked about phase diagrams, major elements, trace elements and isotopes in the lecture portion of the course. The students have also spent at least 7 lab periods looking at a variety of igneous rocks and their textures. In previous labs, they have been asked to relate the things they see in thin section and hand sample to phase diagrams that we have talked about in class, interpret cooling rates and changes in equilibrium based on textures and they have done a previous lab using major elements to calculate norms for volcanic rocks. In several of the previous labs, students have seen a number of disequilibrium textures and have spent some time answering questions about those disequilibrium textures, so they are familiar with what they are looking at in this lab.

The goal of this lab is to give the students experience in the development of a coherent story for a group of temporally and spatially related rocks. I hope, with this lab, to simulate the types of activities that professional igneous petrologists perform on a daily basis. The activities are designed to synthesize the igneous rock portion of the class into one big laboratory exercise and write-up. Students are expected to be able to take the observations they make about thin sections and geochemistry and connect them. They will see a number of textures that suggest mixing, the major and trace elements generally suggest mixing and one suite of rocks (the east side) has good isotopic evidence for crustal involvement whereas the other (the west side) does not. The students' job is to discuss what the geochemistry and thin sections tell them about the processes that modified these magmas.

This lab is also designed to further familiarize students with Microsoft Excel or some other graphing program (some of them use IgPet). I provide students with the Excel files (sent as attachments to their e-mail addresses) to use for plotting and calculating the norm but they are expected to manipulate the data.

In general, students can put together important information into a coherent story. One underlying goal of this exercise (although quite intangible) is to get them to realize that there may be more than one "right answer" to the problem at hand and that they can only interpret the data that is available to them. This can be quite frustrating to some of the students and it takes a bit of prodding sometimes. However, students seem to feel that they learn a lot from this lab and in general it has been quite successful.

The handouts for this lab follow:

Magma Modification in the central Sierra Nevada batholith
Petrology Lab

Imagine that you and your employer (a.k.a., your advisor) want to know more about the chemical and petrologic evolution of continental arc systems. You are particularly interested in the processes that produce the wide variety of plutonic rocks exposed in batholiths associated with these arc systems. Thus, you decide to take a look at the exposed roots of a Mesozoic continental arc in the Western United States in order to better understand the processes that modify the plutonic rocks there. Consequently, your project involves looking at a suite of plutonic rocks from the Sierra Nevada Mountains in California. You climb aboard a plane bound for California (or probably Nevada since that is where the nearest airport is) and you begin to collect samples.

Your advisor has kindly provided you with a map of a portion of the central batholith (see Figure 1). You should take note of the rock types exposed there and also note the close association of granite and diorite in parts of the batholith.

As a good grad student would, you have read numerous papers about calc-alkaline batholiths – many of them suggest that granodiorites in these batholiths result from the mixing of a granitic (rhyolitic) magma with a basaltic (gabbroic) magma. You think that perhaps the granites and diorites/gabbros exposed in your batholith represent end members in this mixing process. Furthermore, you have also discovered, during your literature search, that numerous researchers suggest that, in calc-alkaline batholiths, the source of each of the end member compositions is very different: the granite magma is generated by melting the crust, the diorite/gabbro magma is generated by adding water to the mantle causing melting. Before you leave, you also discover that several workers in the Sierras have suggested that more continental crust is involved in the generation of the batholith on the east side than on the west side. So, you design your fieldwork to test this hypothesis. You visit King's Canyon National Park and collect samples from the east side and from the west side of the batholith. You return with 24 samples. You analyze all of them for major and trace elements and isotopic composition and turn 10 of them into thin sections.

Your advisor wants you to write a short paper about the origin of the variation in the magmatic system of this arc, due in two weeks. So, once again, your boss puts you on a plane and sends you out to collect samples from your field area.

Your advisor wants to see your lab notebook (in which you have recorded your petrographic observations, the names of the rocks and modal mineralogies) and a three page (maximum) typewritten paper about the evolution of these magmas. Use petrographic observations, chemical and isotopic compositions and any other diagrams you might need to make your point. (Figures do not count in the three-page limit.)

The thin section samples are:

East side thin sections	West side thin sections
RC97-1	**NM97-1**
EB97-2	**LP97-1**
EB97-1	**GGG97-3**
BPC97-5	**CC97-1**
BPC97-4	**FP97-2**

YOUR ASSIGNMENT:

1. Make some observations about the spatial relationships of rock types. Record the petrography of each of these samples in your lab notebook. Be sure to include estimates of modal mineralogy, sketches and textural observations. These samples are loaded with textures such as rapakivi, complex zoning (in plagioclase), hornblende rims on quartz, and other rimmed minerals such as plagioclase, sphene, and oxides, etc. For information on how these textures form, see *Petrography to Petrogenesis* by M.J. Hibbard (1995). Also keep your eye out for other familiar textures such as perthite, myrmekite, ophitic textures, etc.
2. Calculate a CIPW norm for samples NM97-1, CC97-1, BPC97-5 and LP97-1, using the spreadsheet program provided. Compare the normative mineralogy to the modal mineralogy. In your lab notebook, explain any discrepancies in a short paragraph.
3. Refer to your modal mineralogies and use the IUGS classification diamond (Streckheisen, 1974; figure 2-2 in your textbook) to name each rock. The names should be recorded in your lab notebook.
4. Several spreadsheets showing the chemical analyses for these rocks, including Sr and Nd isotope analyses [two tables with analyses from east and west side samples, and one table with REE values normalized to chondrite (Sun and McDonough, 1989)] are attached to this sheet. A table with values for a number of normalizing standards for both trace- and rare-earth elements as determined by Sun and McDonough (1989) is also attached. These tables will also be e-mailed to you (so that you don't have to spend a lot of time putting data into spreadsheet form). Use these data to generate some Harker diagrams, REE diagrams, spider diagrams and isotope diagrams to better understand the source(s) and processes that generated this batholith. Remember your hypothesis as you started this project - that OLD continental crust plays a role in the eastern part of the batholith but is absent in the west. Your chemical interpretation should be consistent with what you see in thin section (so connect the two things). Also make sure that you note similarities and differences between the east- and west-side suites.
5. Type up a 3-5 page (maximum, double-spaced) report formulating a hypothesis regarding the source of the magmas and the origin of the variation in the suite of samples (what processes modified these magmas?). Include petrographic, chemical and isotopic data supporting your conclusions- you may wish attach diagrams as illustrations for chemical or isotopic trends.

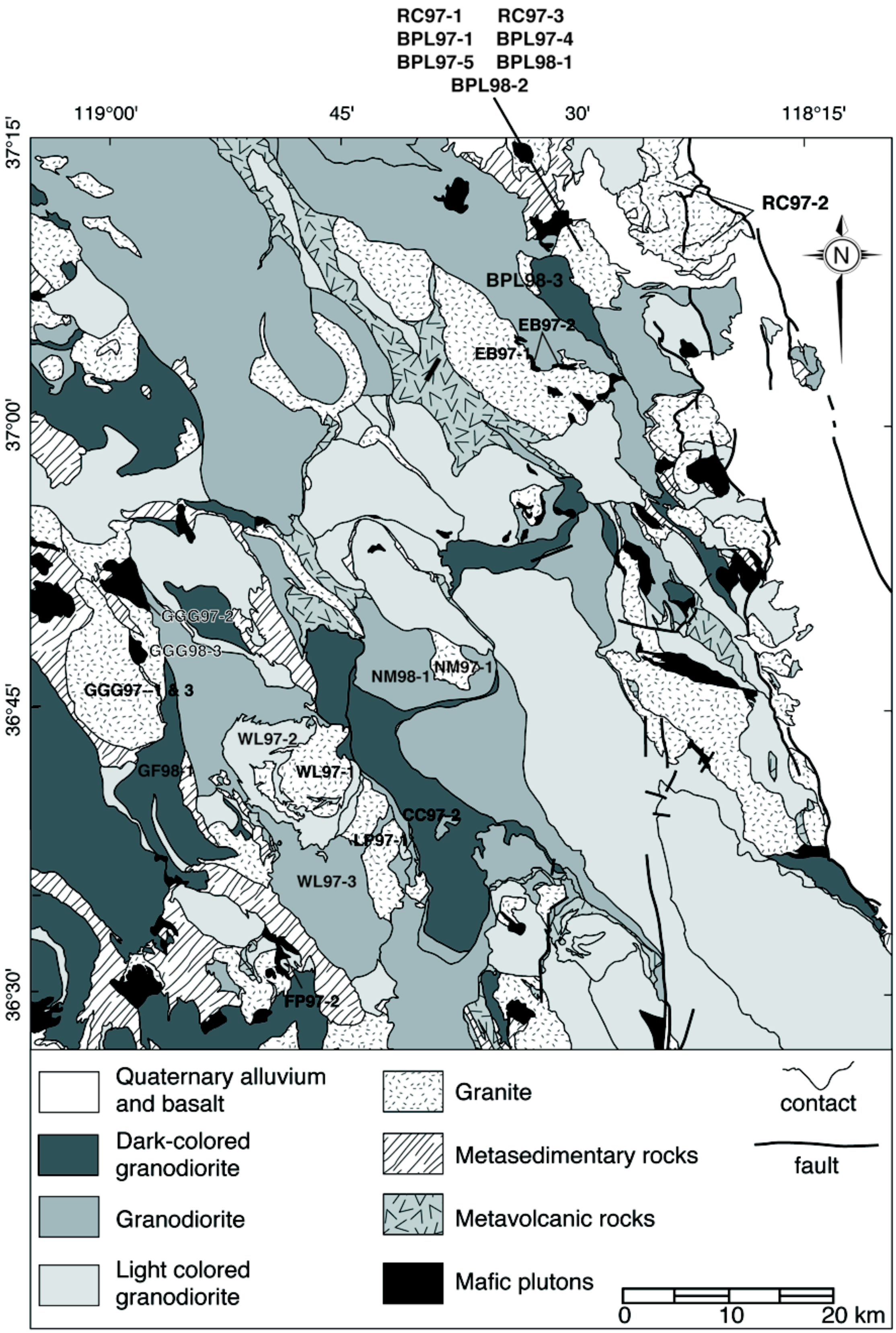

FIGURE 1: Geologic map of King's Canyon-Sequioia National Park (after Moore and Sisson, 1998).

Table 1: East Side Samples

Sample	BPC97-1	BPC97-4	BPC97-5	BPL98-1	BPL98-2	BPL98-3	EB97-1	EB97-2	RC97-1	RC97-2-	RC97-3	SBP98-1
Age (Ma)	92[£]	92[£]	92[£]	92[£]	92[ß]	92[£]	92[Δ]	92[Δ]	92[ß]	92[£]	92[ß]	160[‡]
XRF analyses (in wt. %)												
SiO2	51.91	61.12	54.26	63.41	75.62	58.31	71.78	49.06	76.06	57.83	74.16	65.82
TiO2	1.10	1.09	1.25	0.99	0.21	0.90	0.31	0.88	0.07	1.04	0.23	0.54
Al2O3	15.51	17.04	15.49	16.14	12.91	17.57	14.24	17.13	13.12	16.21	13.56	14.92
Fe2O3	9.04	6.13	8.46	5.59	1.61	7.54	2.32	8.00	0.96	8.02	1.74	4.77
MnO	0.14	0.10	0.14	0.11	0.05	0.15	0.07	0.14	0.14	0.13	0.05	0.08
MgO	8.22	1.96	5.84	1.87	0.35	3.04	0.68	8.31	0.14	3.20	0.41	1.90
CaO	8.57	4.37	9.18	4.22	1.11	5.66	2.22	11.01	0.51	5.88	1.22	3.97
Na2O	2.69	3.93	3.04	3.78	3.26	4.39	3.76	2.47	3.19	3.30	3.39	3.11
K2O	1.17	3.32	1.58	3.16	4.45	1.92	3.51	1.15	5.16	2.76	4.57	3.87
P2O5	0.32	0.40	0.39	0.35	0.07	0.28	0.11	0.31	0.06	0.38	0.08	0.23
Trace element analyses (in ppm)												
Rb *	30.00	93.50	41.70	91.90	137.50	81.20	90.10	52.10	212.50	112.10	154.10	123.10
Sr *	525.40	507.50	506.10	430.50	164.10	623.10	377.30	574.30	111.10	542.80	183.70	528.10
Ba†	395.36	432.61	450.45	483.53	2313.96	1216.23	3891.14	409.38	910.98	786.73	2059.22	1040.00
Zr †	120.92	475.14	129.02	212.31	113.98	207.28	102.63	93.97	59.87	241.97	144.76	149.10
Y †	16.96	22.60	19.79	16.64	8.63	20.58	11.65	18.67	9.23	25.82	9.53	15.10
Nb †	9.88	18.90	11.76	13.66	12.47	15.65	8.93	8.09	19.06	13.21	12.94	10.20
V †	151.73	99.20	183.38	104.73	11.76	143.61	28.08	149.70	1.76	132.65	13.04	0.00
Ni *	144.00	5.70	54.70	4.10	2.70	12.40	3.60	109.30	1.70	10.80	2.50	8.90
Co *	50.00	32.00	41.00	27.00	25.50	34.00	49.00	80.00	11.00	81.00	46.00	29.00
Cr *	308.00	16.00	224.00	16.00	13.60	336.00	13.00	295.00	76.90	19.00	11.20	16.00
Cs †	1.09	1.38	0.94	1.33	1.31	1.71	1.24	3.29	3.96	3.67	1.88	6.80
Hf †	2.81	10.03	3.12	4.94	3.08	5.09	2.51	2.37	2.66	6.18	3.33	
Ta †	0.68	1.75	0.81	0.84	0.75	1.36	0.70	0.52	1.81	1.09	0.95	
Th †	2.82	4.53	3.32	9.97	15.53	7.43	9.63	0.75	4.57	9.37	9.59	
U †	0.83	1.76	1.00	1.98	1.81	3.46	2.33	0.42	2.48	2.42	1.38	
Zn †	63.78	60.30	60.49	56.12	22.01	97.46	36.30	64.81	12.56	99.45	16.15	39.90
Sc †	20.57	5.69	28.70	7.60	2.31	11.10	4.13	27.24	4.96	16.77	2.65	
Pb †	4.79	1.68	5.65	2.01	22.21	6.40	14.27	4.32	25.08	11.90	16.37	9.30
La †	15.93	25.72	19.49	63.55	33.62	37.71	31.18	16.51	2.76	33.95	24.71	10.80
Ce †	34.86	62.43	40.59	103.24	53.26	69.07	51.82	35.57	8.87	74.20	38.80	
Pr †	4.41	7.32	5.28	10.27	4.95	7.76	5.17	4.77	0.86	9.28	3.51	
Nd §	17.10	32.23	19.95	33.50	23.14	27.03	19.86	19.10	7.64	36.33	20.27	29.63
Sm§	3.67	5.53	4.13	4.71	3.04	5.97	3.12	3.99	1.80	6.96	2.66	5.04
Eu †	1.16	1.42	1.32	1.28	0.71	1.46	1.06	1.23	0.21	1.70	0.62	
Gd †	3.43	3.99	4.04	3.86	1.69	4.24	2.19	3.75	0.72	5.96	1.43	
Tb †	0.54	0.64	0.64	0.59	0.27	0.66	0.35	0.59	0.15	0.90	0.23	
Yb †	1.54	2.43	1.79	1.59	0.79	2.03	1.12	1.67	1.05	2.28	0.95	
Lu †	0.24	0.38	0.28	0.25	0.13	0.33	0.17	0.26	0.17	0.35	0.16	
isotope ratios												
εNd(t)	1.10	-2.56	-0.19	-3.75	-6.00	-0.85	-4.55	1.83	-7.78	-1.75	-4.60	-3.88
$^{87}Sr/^{86}Sr_i$	0.704641	0.705833	0.704976	0.706455	0.709385	0.705247	0.707337	0.704648	0.711734	0.705582	0.707146	0.707235

* analyzed by XRF

† analyzed by ICP-MS

§ analyzed by isotope dilution

[Δ] field relations with Lamarck Granodiorite; Coleman et al., 1995

[‡] after Chen and Moore, 1982

[ß] after Stern et al., 1981

[£] based on field relations with dated plutons

Table 2: West Side Samples

Age (Ma	FP97-2 100[£]	GGG98-3 103[£]	GGG97-2 103[£]	GF98-1 98[‡]	CC97-1 98[£]	WL97-3 98[‡]	NM98-1 92[¶]	LP97-1 100[‡]	WL97-2 98[‡]	WL97-1 98[‡]	NM97-1 92[¶]	GGG97-3 103[‡]
XRF analyses (in wt. %)												
SiO2	49.93	55.34	58.17	61.19	60.86	61.34	63.53	64.56	69.50	74.04	73.81	77.64
TiO2	1.69	1.07	1.03	0.89	0.86	0.76	0.70	0.63	0.43	0.17	0.17	0.11
Al2O3	18.53	17.66	17.29	16.56	16.60	16.34	16.96	16.22	15.26	13.71	13.68	11.82
Fe2O3	11.79	7.56	6.96	6.81	5.86	6.24	4.58	4.39	3.24	1.50	1.30	1.37
MnO	0.19	0.12	0.12	0.11	0.09	0.11	0.07	0.08	0.07	0.04	0.04	0.02
MgO	4.62	5.11	3.69	2.68	2.62	2.45	2.04	1.17	0.79	0.28	0.23	0.10
CaO	8.67	7.99	6.59	5.63	5.52	5.32	4.78	2.98	2.47	1.28	0.97	1.21
Na2O	3.01	2.82	3.15	3.14	3.26	3.32	3.85	3.94	3.63	3.32	3.04	3.02
K2O	0.75	1.19	1.66	2.35	2.88	2.43	2.83	4.16	3.79	4.34	6.08	3.72
P2O5	0.29	0.20	0.18	0.18	0.20	0.16	0.23	0.20	0.14	0.05	0.06	0.02
Trace element analyses (in ppm)												
Rb *	20.10	32.30	56.20	89.20	111.50	102.70	116.70	127.50	124.50	168.10	279.30	93.60
Sr *	423.40	555.10	487.40	373.50	448.40	346.20	638.10	325.10	342.90	180.30	186.40	309.10
Ba†	*499.20*	418.17	565.27	415.54	622.51	395.32	745.22	1451.86	1655.99	1643.88	1502.87	8837.57
Zr †	*123.90*	107.54	98.55	171.74	178.14	229.46	153.35	379.96	248.32	109.80	160.00	101.64
Y †	*29.90*	13.40	22.53	21.23	29.91	24.36	20.24	23.95	14.21	13.14	12.01	9.44
Nb †	*9.10*	6.75	11.05	11.11	13.40	12.42	13.24	20.77	8.87	11.38	17.91	8.60
V †	*168.17*	142.26	130.35	108.31	127.40	104.44	98.71	42.28	30.38	9.65	8.56	1.23
Ni *	3.50	16.80	10.10	4.10	4.30	2.10	6.10	3.60	3.30	2.10	2.20	2.50
Co *	68.00	54.00	55.00	65.00	66.00	49.00	37.00	37.00	29.00	28.90	25.50	31.30
Cr *	22.00	255.00	392.00	443.00	16.00	17.00	34.80	16.00	13.00	120.30	32.00	14.80
Cs †	*3.90*	4.16	2.77	2.08	2.97	3.68	2.40	2.43	4.48	2.77	8.00	2.18
Hf †	*3.07*	2.86	2.64	4.52	4.87	6.51	4.18	8.79	6.16	3.24	4.55	2.92
Ta †	*0.32*	0.48	0.81	0.91	0.98	1.09	1.79	1.01	0.67	1.41	2.55	0.54
Th †	*1.82*	2.45	11.87	11.62	33.91	12.50	19.96	25.14	14.03	20.10	40.90	22.04
U †	*0.25*	0.53	1.08	1.91	4.30	3.73	5.40	2.95	2.00	3.25	7.09	2.56
Zn †	*123.20*	88.15	100.74	74.45	79.88	74.88	74.67	70.18	67.34	31.02	46.49	33.32
Sc †	*17.13*	17.96	19.61	9.96	13.08	12.77	8.87	7.38	5.61	2.26	4.75	4.62
Pb †	*1.80*	6.82	8.54	2.89	2.82	5.65	3.46	14.16	16.79	32.55	56.16	28.12
La †	*37.42*	14.63	45.33	32.54	35.58	18.44	35.93	88.19	37.99	25.29	38.91	52.17
Ce †	*76.04*	31.59	101.11	66.12	74.16	43.82	68.91	134.48	65.41	37.63	56.43	92.82
Pr †	*8.92*	4.21	12.27	7.76	9.19	5.83	8.19	15.31	6.59	4.37	5.85	9.45
Nd §	*52.41*	16.04	38.01	45.58	32.47	23.42	27.25	34.30	20.32	18.31	19.99	31.79
Sm§	*9.55*	3.43	6.98	8.30	6.25	4.98	4.94	7.15	3.15	3.19	3.09	3.97
Eu †	*1.41*	1.22	1.52	1.23	1.35	1.19	1.34	1.50	1.09	0.57	0.50	2.15
Gd †	*5.17*	3.31	5.77	4.50	5.98	4.70	4.42	5.74	2.75	2.14	1.96	2.60
Tb †	*0.81*	0.50	0.86	0.71	0.95	0.75	0.68	0.88	0.44	0.34	0.31	0.38
Yb †	*2.24*	1.08	1.86	1.95	2.63	2.46	1.84	2.20	1.41	1.15	1.15	1.04
Lu †	*0.34*	0.16	0.28	0.30	0.40	0.39	0.29	0.35	0.23	0.19	0.19	0.17
isotope ratios												
E Nd (t)	*-4.50*	-3.55	*-4.53*	-2.05	-4.65	*-4.87*	-4.91	-5.86	-3.83	-4.55	-4.51	*-5.03*
$^{87}Sr/^{86}Sr_i$	0.706104	0.706591	*0.706128*	*0.706131*	*0.706405*	0.706652	0.706651	0.706800	0.706173	0.706394	0.706338	0.707484

* analyzed by XRF
† analyzed by ICP-MS
§ analyzed by isotope dilution

‡ after Chen and Moore, 1982, all other ages based on field relatio
¶ A. Glazner, J. Bartley and D. Coleman, work in progress
£ based on field relations with dated plutons

TABLE 3: REE DATA NORMALIZED TO CHONDRITE (Sun and McDonough, 1989)

East side samples

(Atomic Number)	REE	BPC97-1	BPC97-4	BPC97-5	BPL98-1	BPL98-2	BPL98-3	EB97-1	EB97-2	RC97-1	RC97-2	RC97-3
57	La (n)	67.231	108.523	82.245	268.144	130.727	146.615	121.218	69.659	14.680	143.250	96.144
58	Ce (n)	56.966	102.006	66.316	168.690	80.598	104.530	78.421	58.120	16.008	121.238	58.701
59	Pr (n)	44.893	74.981	53.616	104.703	51.048	74.525	50.802	48.354	8.393	95.458	38.920
60	Nd (n)	36.052	53.278	42.503	66.720	31.640	55.000	34.319	39.320	5.850	75.406	24.930
62	Sm (n)	22.519	28.605	26.805	29.391	12.795	29.249	16.355	25.177	4.428	43.746	10.507
63	Eu (n)	20.023	24.416	22.800	22.028	12.019	24.801	17.988	21.149	3.578	29.369	10.569
64	Gd (n)	16.709	19.437	19.644	18.800	7.633	19.132	9.861	18.271	3.249	28.995	6.432
65	Tb (n)	14.459	17.090	17.177	15.795	7.087	17.385	9.252	15.906	4.012	24.014	6.164
66	Dy (n)	12.167	14.292	14.268	12.396	5.269	13.634	7.147	13.242	3.905	19.127	4.900
67	Ho (n)	10.719	13.215	12.664	10.415	4.210	11.186	5.802	11.828	3.779	15.881	4.215
68	Er (n)	10.143	13.612	11.821	10.064	4.349	11.077	5.953	11.105	4.366	14.822	4.521
70	Yb (n)	9.043	14.265	10.547	9.362	4.190	10.811	5.974	9.804	5.659	13.392	5.126
71	Lu (n)	9.392	15.062	10.956	10.027	4.643	11.843	6.282	10.069	6.003	13.669	5.578

West side samples

(Atomic Number)	REE	CC97-1	GF98-1	GGG97-2	GGG97-3	GGG98-3	LP97-1	NM97-1	NM98-1	WL97-1	WL97-2	WL97-3
57	La (n)	138.342	137.303	191.248	202.838	61.748	343.128	151.401	139.780	98.378	147.822	71.751
58	Ce (n)	112.239	108.038	165.210	140.477	51.624	203.454	85.377	104.246	56.929	98.962	66.288
59	Pr (n)	88.859	77.980	126.212	94.171	43.015	152.710	63.219	81.598	47.904	63.488	53.437
60	Nd (n)	68.010	56.373	89.689	61.090	35.994	98.013	39.252	61.136	33.233	42.039	44.276
62	Sm (n)	40.288	32.646	46.361	24.371	23.183	44.431	16.144	32.680	16.023	19.420	30.510
63	Eu (n)	22.872	21.184	26.250	36.357	21.002	25.424	8.449	22.818	9.738	18.530	20.276
64	Gd (n)	26.947	21.885	28.096	11.737	16.127	25.846	8.832	19.893	9.654	12.368	21.167
65	Tb (n)	25.184	18.928	23.089	9.982	13.293	23.365	8.187	18.042	9.001	11.697	19.918
66	Dy (n)	19.998	15.382	17.658	6.919	10.398	16.973	5.999	13.654	6.879	8.972	16.199
67	Ho (n)	16.384	13.080	14.034	4.871	8.588	13.000	4.656	10.804	5.552	7.395	13.930
68	Er (n)	15.781	12.393	12.956	5.321	7.667	13.067	5.081	10.540	5.704	7.561	13.676
70	Yb (n)	14.028	11.479	10.917	5.527	6.374	11.859	6.238	9.958	6.233	7.595	13.283
71	Lu (n)	14.354	11.807	11.062	6.206	6.395	12.318	6.860	10.219	6.807	8.256	13.817

Trace element normalization standards from Sun and McDonough, 1989				
element *	Chondrite	Primitive mantle	NMORB	EMORB
Cs	0.188	0.0079	0.007	0.063
Rb	2.32	0.635	0.56	5.04
Ba	2.41	6.989	6.3	57
Th	0.029	0.085	0.12	0.6
U	0.008	0.021	0.047	0.18
Nb	0.246	0.713	2.33	8.3
Ta	0.014	0.041	0.132	0.47
La	0.237	0.687	2.5	6.3
Ce	0.612	1.775	7.5	15
Pb	2.47	0.071	0.3	0.6
Pr	0.095	0.276	1.32	2.05
Sr	7.26	21.1	90	155
Nd	0.467	1.354	7.3	9
Zr	3.87	11.2	74	73
Hf	0.1066	0.309	2.05	2.03
Sm	0.153	0.444	2.63	2.6
Eu	0.058	0.168	1.02	0.91
Gd	0.2055	0.596	3.68	2.97
Tb	0.0374	0.108	0.67	0.53
Dy	0.254	0.737	4.55	3.55
Ho	0.0566	0.164	1.01	0.79
Er	0.1655	0.48	2.97	2.31
Yb	0.17	0.493	3.05	2.37
Y	1.57	4.55	28	22
Lu	0.0254	0.074	0.455	0.354
K2O (wt. %)	0.065651	0.030115	0.072276	0.252966
K (ppm)	545	250	600	2100
Tl	0.14	0.005	0.0014	0.013
W	0.095	0.02	0.01	0.092
Mo	0.92	0.063	0.31	0.47
P	1220	95	510	620
TiO2 (wt %)	0.074883	0.218759	1.278901	1.009659
Ti (ppm)	445	1300	7600	6000
Sn	1.72	0.17	1.1	0.8
Sb	0.16	0.005	0.01	0.01
Li	1.57	1.6	4.3	3.5

* in ppm unless otherwise indicated

REE normalization standards from Sun and McDonough, 1989					
element (ppm)	Chondrite	Prim. Mantle	NMORB	EMORB	OIB
La	0.237	0.687	2.5	6.3	37
Ce	0.612	1.775	7.5	15	80
Pr	0.095	0.276	1.32	2.05	9.7
Nd	0.467	1.354	7.3	9	38.5
Sm	0.153	0.444	2.63	2.6	10
Eu	0.058	0.168	1.02	0.91	3
Gd	0.2055	0.596	3.68	2.97	7.62
Tb	0.0374	0.108	0.67	0.53	1.05
Dy	0.254	0.737	4.55	3.55	5.6
Ho	0.0566	0.164	1.01	0.79	1.06
Er	0.1655	0.48	2.97	2.31	2.62
Yb	0.17	0.493	3.05	2.37	2.16
Lu	0.0254	0.074	0.455	0.354	0.3